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Resource Management of Fog Computing in Future Networks

by

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Certificate of Authorship/Originality

I, Xinchen Lyu declare that this thesis, is submitted in fulfilment of the requirements for the award of doctor of philosophy, in the Faculty of Engineering and Information Technology at the University of Technology Sydney. This thesis is wholly my own work unless otherwise reference or acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis. I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of the requirements for a degree except as fully acknowledged within the text. This thesis is the result of a research candidature jointly delivered with Beijing University of Posts and Telecommunications as part of a Collaborative Doctoral Research Degree. This research is supported by the Australian Government Research Training Program.

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ABSTRACT

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By enabling task offloading among edge network nodes (such as base stations, switches, and routers), fog computing is able to process the computationally demanding tasks at the point of capture. It has the potential to provide low-latency services, increase network capacity, and relieve network congestions. In this thesis, we focus on three exemplary scenarios of fog computing, including (1) single-cell multiuser fog computing to jointly optimize task offloading and resource allocation for different applications with heterogeneous quality of service requirements; (2) fog computing among selfish devices to design incentive mechanism and efficient management of task offloading, processing, and result retrieving; and (3) fog computing across large-scale edge cloud for scalable and distributed resource management in the presence of a large number of geo-distributed edge servers.

We present five new approaches to address the challenges for efficient and scalable fog computing in the three scenarios. The first three approaches are for the first scenario, i.e., single-cell multiuser fog computing, for three different types of applications, including delay-tolerant, delay-sensitive, and data-partition tasks. The fourth approach is for the second scenario, where distributed tit-for-tat mechanism is proposed to incentivize the cooperation of selfish devices. The fifth approach is for the last scenario, where collaborative regions are created for preventing tasks being offloaded beyond the vicinity of the point of capture in large-scale networks.

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List of Publications

Journal Papers

J-1 . **X. Lyu, C. Ren, W. Ni, H. Tian, R. P. Liu, Y. Jay Guo.** *"Multi-timescale Decentralized Online Orchestration of Software-Defined Networks" in* ***IEEE Journal on Selected Areas in Communications****,* 2018, DOI: 10.1109/JSAC.2018.2871310.

J-2 . **X. Lyu, C. Ren, W. Ni, H. Tian, R. P. Liu.** *"Distributed Optimization of Collaborative Regions in Large-Scale Inhomogeneous Fog Computing" in* ***IEEE Journal on Selected Areas in Communications****,* vol. 36, no. 3, pp. 574-586, March 2018.

J-3 . **X. Lyu, W. Ni, H. Tian, R. P. Liu, X. Wang, G. B. Giannakis, A. Paulraj.** *"Optimal Schedule of Mobile Edge Computing for Internet of Things Using Partial Information" in* ***IEEE Journal on Selected Areas in Communications****,* vol. 35, no. 11, pp. 2606-2615, Nov. 2017.

J-4 . **X. Lyu, H. Tian, L. Jiang, A. Vinel, S. Maharjan, S. Gjessing, Y. Zhang.** *"Selective Offloading in Mobile Edge Computing for the Green Internet of Things" in* ***IEEE Network****,* vol. 32, no. 1, pp. 54-60, Jan.-Feb. 2018.

J-5 . **X. Lyu, W. Ni, H. Tian, R. P. Liu, X. Wang, G. B. Giannakis, A. Paulraj.** *"Distributed Online Optimization of Fog Computing for Selfish Devices with Out-of-Date Information" in* ***IEEE Transactions on Wireless Communications****,* 2018, DOI: 10.1109/TWC.2018.2869764.

J-6 . **X. Lyu, H. Tian, W. Ni, Y. Zhang, P. Zhang, R. P. Liu.** *"Energy-Efficient Admission of Delay-Sensitive Tasks for Mobile Edge Computing" in* ***IEEE Transactions on Communications****,* vol. 66, no. 6, pp. 2603-2616,

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J-7 . **X. Lyu, H. Tian, C. Sengul, P. Zhang.** *"Multiuser Joint Task Offloading and Resource Optimization in Proximate Clouds" in* ***IEEE Transactions on Vehicular Technology****,* vol. 66, no. 4, pp. 3435-3447, April 2017.

J-8 . **X. Lyu, H. Tian, W. Ni, R. P. Liu, P. Zhang.** *"Adaptive Centralized Clustering Framework for Software-Defined Ultra-Dense Wireless Networks" in* ***IEEE Transactions on Vehicular Technology****,* vol. 66, no. 9, pp. 8553-8557, Sept. 2017.

J-9 . **X. Lyu, H. Tian.** *"Adaptive Receding Horizon Offloading Strategy Under Dynamic Environment" in* ***IEEE Communications Letters****,* vol. 20, no. 5, pp. 878-881, May 2016.

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Abbreviation

Internet of Things - IoT

Quality of service - QoS

Non-deterministic polynomial hard- NP-hard

Mixed integer programming - MIP

Dynamic programming- DP

Time-division multiple access - TDMA

Orthogonal frequency-division multiple access - OFDMA

Alternating direction method of multipliers - ADMM

Quality of experience - QoE

Base station - BS

Long-term evolution - LTE

Mixed integer non-linear programming - MINLP

KarushKuhnTucker - KKT

Cumulative distribution function - CDF

Integer programming - IP

Linear programming - LP

Independent and non-identically distributed - i.n.d.

Independent and identical distributed - i.i.d.

Round robin - RR

Proportional fair - PF

Device-to-Device - D2D

Precision time protocol -PTP

Timing-sync protocol for sensor networks - TPSN

First-in-first-out - FIFO

Left-hand-side - LHS

Right-hand-side - RHS

Neighbor discovery protocol - NDP

Head-of-line - HOL